

REPORT

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FINAL REPORT

On

Effects of Possible Soil Boron Contamination on Seed Germination

To

Whirlpool Corporation

Clyde Division

JANUARY 9, 1989

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EFFECTS OF POSSIBLE SOIL BORON CONTAMINATION
ON SEED GERMINATION

WHIRLPOOL CORPORATION - CLYDE DIVISION

January 9, 1989

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INTRODUCTION

On 19 September 1988, nine and eight soil samples were collected from the Amert and Leach sites, respectively. The Amert and Leach sites, as well as the individual soil sampling points, are shown in Figures 1 and 2. At the Amert site, soil samples were collected from various locations including an existing corn field, a waterway area, and one area west of the waterway. During periods of high rainfall, surface water drains through the waterway area to the north from a topographically high region to the south, which contains the Amert disposal site. At the time of sampling this waterway area was dry. Vegetative cover in the waterway area was dominated by the dicotyledon lambsquarter (Chenopodium album L.), while the area west of the waterway was predominately annuals grasses. At the Leach site, soil samples were collected from an existing oat field and from three areas below and west of the site. All soil samples, with the exception of sites 1A and 13, were sampled from the surface to approximately 8 inches in depth. Sites 1A and 13 were sampled from the surface to approximately 2 inches in depth.

The soil samples were returned to Battelle, air-dried, and ground to pass a No. 10 (2 mm) sieve. A seed germination test was conducted on each of the 17 soil samples. Soil analyses, including plant available boron (B), exchangeable sodium (Na), pH, and soluble salts (electrical conductivity) were also conducted. A brief description of the methods used follows.

MATERIALS AND METHODS

Boron Analysis

Plant-available boron for Ohio soils typically ranges from 0.5 - 1 $\mu\text{g/g}$ (Watson, M., telephone conversation). The procedure followed for determination of plant available B involved addition of 20 ml of a 0.1 % calcium chloride solution to 10 grams of soil, after which the mixture was boiled for approximately 5 minutes. The suspensions were then centrifuged for 15 minutes at 2700 G and filtered. The filtrates were analyzed for B by Inductive Coupled Argon Plasma Spectrometry (ICP).

Exchangeable Sodium

Exchangeable Na is usually that portion of the soil Na that is considered plant available and for Ohio soils, typically ranges from 9-23 $\mu\text{g/g}$ (Watson, M., telephone conversation). The procedure followed for the determination of exchangeable Na involved addition of 10 ml of 1N ammonium acetate to 10 grams of soil, after which the mixture was placed on an oscillating shaker for 5 minutes. The suspension was filtered and the filtrate analyzed for Na by Atomic Absorption Spectroscopy.

pH

The soil pH was determined on a 1:1 (soil:water) mixture with a combination pH electrode. After preparing the mixture, the samples were stirred and allowed to stand for approximately 10 minutes. The suspensions were restirred, and the pH was obtained.

Seed Germination

Approximately 40 grams of each air-dried soil sample was placed in petri plates (100 x 12 mm). Ten corn (Zea Mays L., variety: Boone County White) seeds were then placed in each plate and covered with soil. The study

was conducted at a high moisture level in triplicate plates. Approximately 10 ml of deionized water was added to each plate to achieve the high soil moisture. All plates were placed in an environmental chamber at approximately 25 °C in the dark. After approximately 10 days of dark incubation, the plates were removed, and percent germination was determined.

Electrical Conductivity

The degree of salinity is usually measured in water extract of a soil sample as electrical conductivity. This is expressed in mmhos cm^{-1} , which is the reciprocal of electrical resistance. The higher the salt concentration of the soil extract, the higher the electrical conductivity (Mengel and Kirby, 1979). Electrical conductivity in mmhos cm^{-1} at 25 °C was determined on filtrates obtained from soil:water (1:2) extracts. The mixtures were allowed to stand for approximately 60 minutes before the conductivity measurements were made on the filtrates. The conductivity measurements were determined with a Solu-Bridge electrode. These analyses as well as those for plant available boron and exchangeable sodium were performed at the Research Extension Analytical Laboratory, Wooster, Ohio under a Battelle purchase order agreement.

RESULTS AND DISCUSSION

Soil Boron and Sodium

Amert Site

Plant available boron (B) and exchangeable sodium (Na) data for the Amert site are shown in Figure 1. Boron concentrations at the Amert site ranged from 1 to 152 $\mu\text{g/g}$, while Na concentrations ranged from 8 to 648 $\mu\text{g/g}$. Both B and Na followed similar patterns. An increase in B was usually accompanied by an increase in Na. The highest B and Na (152 and 648 $\mu\text{g/g}$) levels occurred at sampling point 1A, which was a surface (0-2 inch) sample in which visible white salt residue was observed. The lowest levels of B and Na

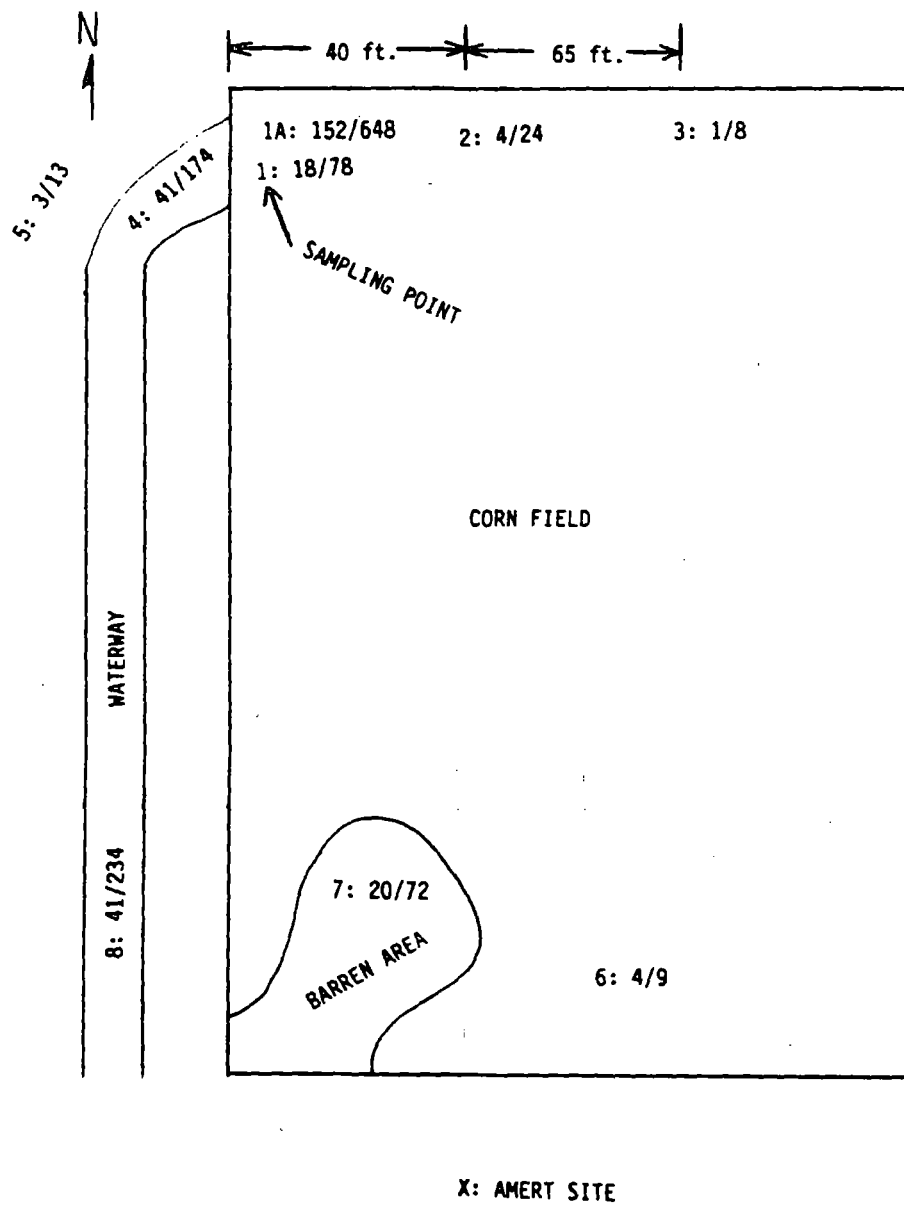


FIGURE 1. BORON/SODIUM LEVELS ($\mu\text{g/g}$) AT THE AMERT SITE

(1 and 8 $\mu\text{g/g}$) observed were at sampling point 3, which was collected as a background sample. A general pattern observed was that as B and Na levels increased, such as when progressing from sampling points 3 to 1, the corn was less healthy. Corn at sampling point 1A was short and stubby, while corn at sampling point 3 appeared normal and healthy.

Soil B and Na levels at sampling point 7 in the barren portion (southwest corner) of the corn field were 20 and 72 $\mu\text{g/g}$, while soil B and Na levels in healthy corn (sampling point 6) were 4 and 9 $\mu\text{g/g}$. The waterway (sampling points 4 and 8) area also had elevated B and Na levels (Figure 1). Soil B and Na levels at sampling point 5, in the grassy area to the west of the waterway, were considerably lower than in the waterway area.

Leach Site

The highest B and Na levels in the oat field north of the Leach site occurred on the gently sloping (east to west slope) barren portion of the oat field (Figure 2). Soil B and Na levels in this area ranged up to 398 and 1050 $\mu\text{g/g}$ (Figure 2). Upgrade (sampling point 9) and downgrade (sampling point 12) of the barren portion of the oat field, where oats were established, B and Na levels were considerably lower.

B and Na levels at sampling point 14, a grassy area, were 10 and 11 $\mu\text{g/g}$. Levels of B and Na at sampling points 15 and 16, both of which were barren, were 156 and 518 and 371 and 1500 $\mu\text{g/g}$, respectively. The soil sample collected at sampling point 16 contained fritted material. This fritted material was not observed at sampling points 14 and 15.

pH, Seed Germination, and Soluble Salts

Soil pH, percent corn germination, and electrical conductivity for all 17 soils are shown in Table 1.

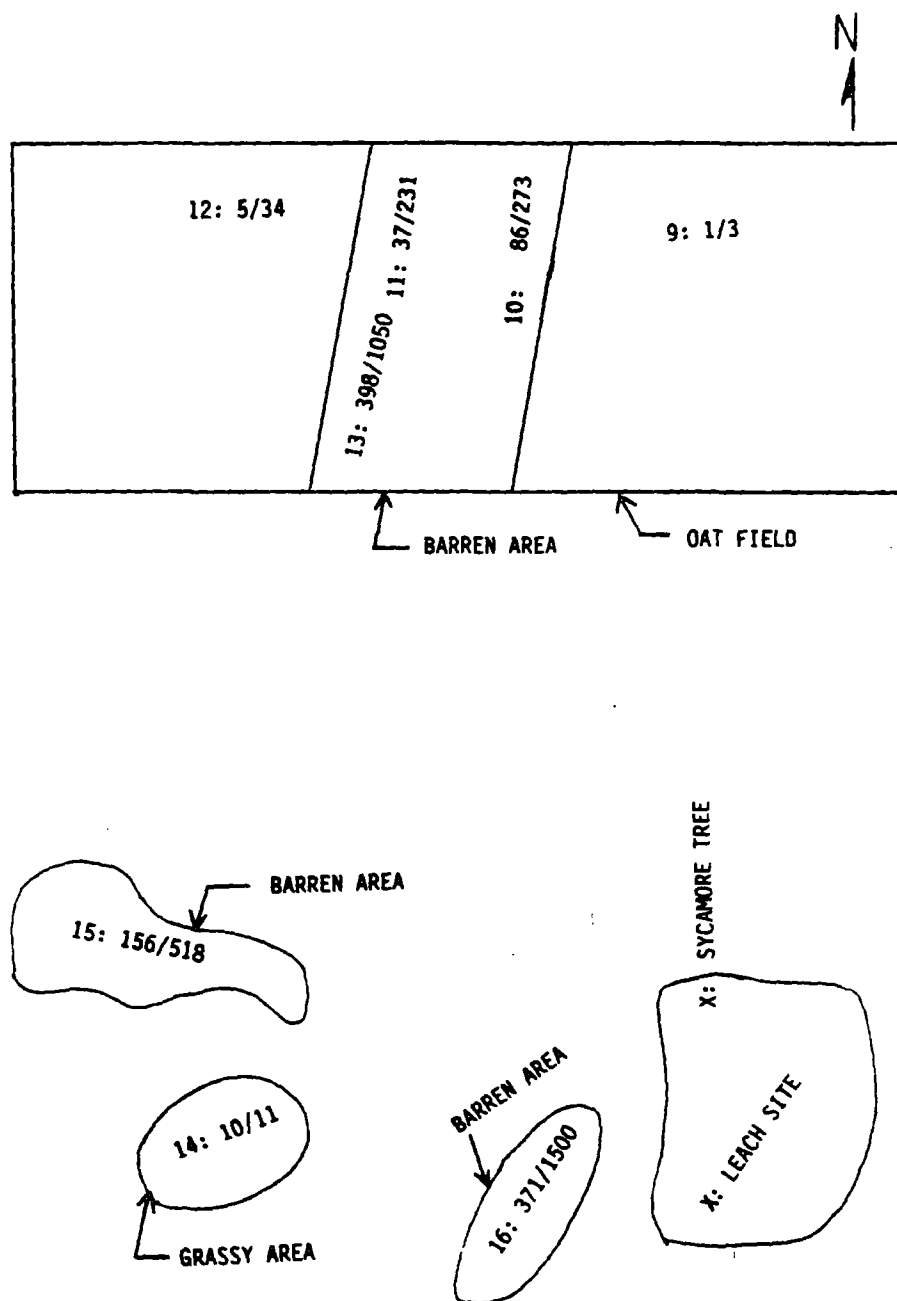


FIGURE 2. BORON/SODIUM LEVELS ($\mu\text{g/g}$) AT THE LEACH SITE

TABLE 1. SOIL pH, PERCENT CORN GERMINATION,
AND ELECTRICAL CONDUCTIVITY

Sampling Point	pH	Percent Germination(a)	Electrical Conductivity mmhos cm ⁻¹ (b)
1A	6.9	100	0.60
1	7.0	100	0.31
2	5.9	100	0.51
3	5.5	100	0.47
4	7.6	100	0.24
5	7.2	100	0.14
6	6.0	100	0.21
7	6.1	100	0.45
8	7.9	100	0.19
9	6.4	100	0.08
10	9.1	100	0.42
11	7.3	100	0.14
12	6.6	100	0.10
13	6.8	100	0.74
14	8.0	100	0.12
15	9.2	100	0.48
16	9.4	77	0.96

(a) Results are average of 3 replicates (10 corn seeds/replicate).

(b) Electrical conductivity of soil extract; water:soil = 2:1.

Soil pH

At the corn field north of the Amert site (sampling points 1, 2, 3, 6, and 7) site, pH ranged from slightly acid (pH 5.5) to neutral (pH 7.0). Soil pH in the waterway (sampling points 4 and 8) was 7.6 and 7.9, respectively. In the grassy area outside the waterway (sampling point 5), the pH was 7.2. Soil pH in the oat field at the Leach (sampling points 9, 10, 11, 12, and 13) site generally ranged from 6.4 to 7.3, with a pH of 9.1 observed at sampling point 10. Soil pH for sampling points 14, 15, and 16 were 8.0, 9.2, and 9.4, respectively.

Seed Germination

At the high moisture level, which was conducted at a moisture level that is considered normal for a seed germination test, 100 percent germination was obtained in all soils with the exception of soil sample 16 where 77 percent germination was observed.

Electrical Conductivity

The electrical conductivity for the 17 sampling sites ranged from 0.08 (sampling point 9) to 0.96 (sampling point 16) mmhos cm^{-1} . While the majority of the values fall within the normal range expected in agricultural fields, the salt concentration at site 16 (0.96 mmhos cm^{-1}) is at a level that may inhibit seed germination (Watson, M., telephone conversation).

The highest soluble salt (0.60 mmhos cm^{-1}) concentration observed in the corn field was obtained from the surface soil collected at sampling point 1A where salt precipitate was observed on the soil surface. While the corn was slightly shorter at this sampling location, this level of soluble salt would not be expected to have adverse effects on the growing corn plant. Severe injury to existing plants is not expected until salinity levels reach approximately 3 mmhos cm^{-1} (Watson, M., telephone conversation). It should be noted that all sampling locations at the Amert and Leach sites registered levels below or equal to 0.96 mmhos cm^{-1} . The barren portion, approximately

2500 ft² in size, of the corn field (sampling point 7) had a salinity level (0.45 mmhos cm⁻¹) below that expected to result in either poor seed germination or plant injury.

SUMMARY AND CONCLUSIONS

1. Elevated plant available B and exchangeable Na concentrations were observed in the "waterway" area of the Amert site and a barren area in the southwest corner of the corn field to the east of the "waterway". Elevated boron and sodium levels were also observed in barren portions of an oat field and a grassy area at the Leach site. Boron and sodium concentrations in these areas exceeded typical Ohio soil B and Na contents of 0.5-1 and 9-23 $\mu\text{g/g}$, respectively.
2. Elevated pH was also observed in 5 of the 12 soils highest in boron and sodium.
3. Crop (corn or oats) health appeared to decline with increasing boron and sodium content. In areas not containing crops, high B and Na were also observed in areas that were either barren (Leach site) or dominated by a dicot, lambsquarter (Amert site), which has a higher tolerance and higher boron requirement than monocots (Mengel and Kirby, 1979).
4. The seed germination test was inconclusive since 100 percent germination was observed in all soil samples with the exception of the soil from sampling point 16, where germination was slightly inhibited.
5. The sources of the elevated boron and sodium are probably the Amert and Leach dump sites located in topographically elevated areas immediately to the south (Amert site) or southeast (Leach site) of the sampling areas.
6. This was a limited sampling and analysis program which was not intended to: (a) define the full extent (in terms of area as well as depth) of the

zones containing elevated boron and sodium; (b) analyze other chemical constituents that may be present; (c) determine boron and sodium migration mechanisms and rates; or (d) recommend possible remediation alternatives.

REFERENCES

Mengel, K and E.A. Kirby. 1979. Principles of Plant Nutrition. Der Bund AG, Bern/Switzerland.

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